Historic, archived document

Do not assume content reflects current
scientific knowledge, policies, or practices.

SOUND INSULATION IN A MODULAR MOTEL

by

J. B. Grantham, *Forest Products Technologist*

and

T. B. Heebink, *Structural Engineer*

ABSTRACT

*Field-measured resistance to sound transmission
in a two-story modular motel assembled from factory-
built, three-dimensional wood-framed units was generally
acceptable. Walls and floors separating rental units
had field sound transmission classes (FSTC) of 47 and 49,
respectively; floors had impact insulation classes (IIC)
of 71 and 42 for carpeted and tile covered areas, respec-
tively. A series of laboratory tests was conducted on
the motel wall as built and as modified in four ways, to
determine the best arrangement of structural materials
for sound insulation. The tests demonstrated that the
exterior sheathing, which improves the rigidity and
resistance to weather of three-dimensional units during
transportation and erection, may reduce sound insulation
slightly.*

Keywords: *Acoustic insulation, prefabricated
buildings, wood construction.*

INTRODUCTION

Modular motels--built from three-dimensional units which are completely factory finished so as to require only connection in the field--have gained popularity with some builders. It could be assumed that motels constructed with factory-built modules will provide excellent resistance to sound transmission because of the double partitions that are formed when modular units are joined horizontally or vertically.

In October 1971, we had an opportunity to measure the sound insulation achieved in a two-story motel complex assembled from 102 factory-fabricated modules. Almost every module represented a single living unit, and these were arranged as shown in figure 1.

The resistance to airborne sound transmission of the party wall formed between two second-story units and that of a floor-ceiling assembly formed between a first- and second-story unit was measured in the field in accordance with the detailed procedures described in American Society for Testing and Materials (ASTM) Designation E336-71.[1] Resistance of the floor-ceiling assembly to impact sound transmission also was measured in accordance with the procedures of International Organization for Standardization (ISO) R/140.[2]

The floor-ceiling combination and the party wall that resulted from stacking individual modules is illustrated in figure 2. The party wall between units was composed of two separate walls an inch apart and could be expected to provide excellent resistance to sound transmission because the inner wall surface of one living unit is so well isolated from the inner wall surface of an adjacent unit. Likewise, excellent resistance to vertical noise transmission might be expected because of the isolation between the floor frame of a second floor unit and the ceiling frame of a first floor unit.

In fact, both the party wall and the floor-ceiling assembly did provide an acceptable level of airborne sound insulation with field sound transmission classes (FSTC) of 47 and 49, respectively. The impact insulation class (IIC) of the floor-ceiling assembly, when determined with carpet and pad in place, was an acceptable 71.

However, experience indicates that these same levels of sound insulation could have been obtained with simpler construction or less material. The designer had hoped for somewhat higher levels of sound insulation.

[1] American Society for Testing and Materials. Designation E336-71. Annual ASTM Standards, Part 14, 1971.

[2] International Organization for Standardization. Designation ISO R/140. Field and laboratory measurements of airborne and impact sound transmission, 1960.
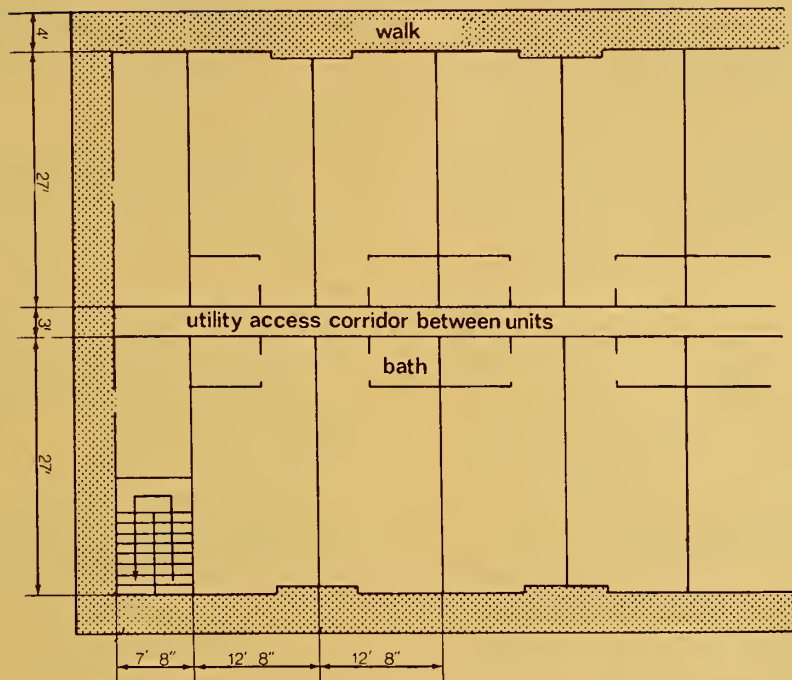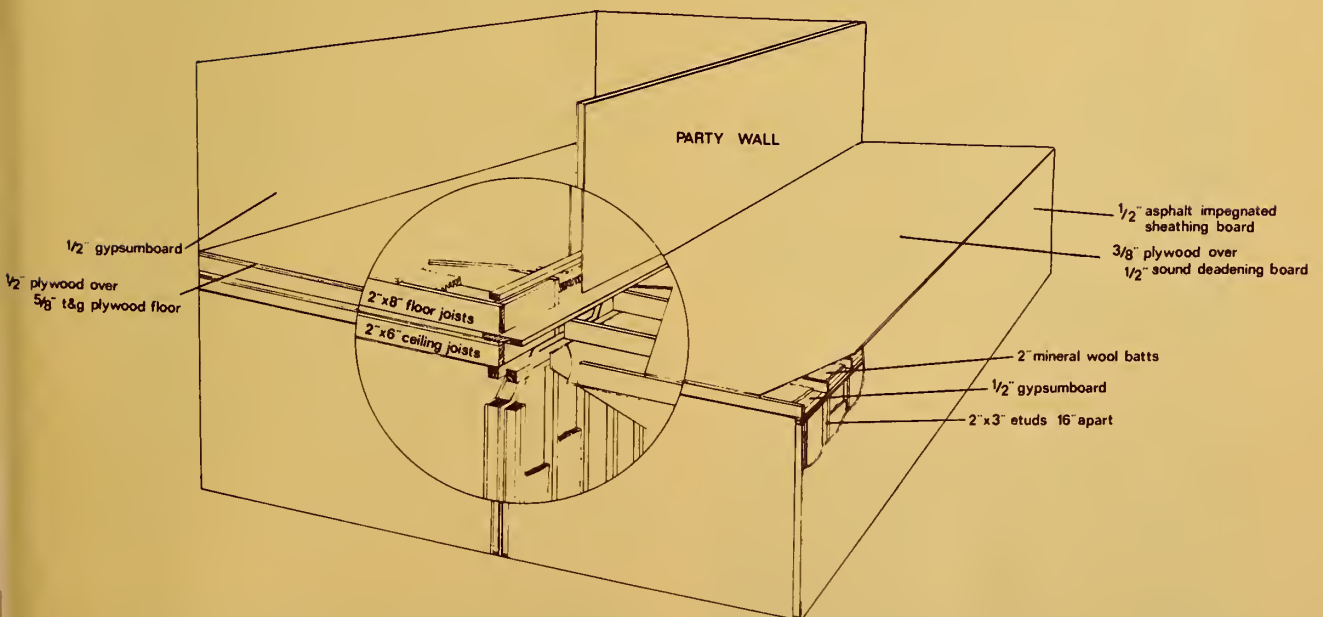
Figure 1.--Floor plan (first and second floors).

Figure 2.--Construction details of three modules as assembled.

3

It was hypothesized that the exterior materials which were used to stiffen the modules and protect them from weather during transportation and erection may have reduced rather than increased the overall resistance to sound transmission.

To demonstrate this possibility, we measured the airborne sound transmission of the party wall as it was built in the field. Then we modified the wall in four ways and measured the airborne sound transmission in an acoustical laboratory.[3] The modifications included: (1) removing the exterior fiberboard sheathing from each wall frame (fig. 3b); (2) adding 1/2-inch-thick sound-deadening board on one wall and laminating the gypsum board over it (fig. 3c); (3) replacing the fiberboard sheathing of the original wall with nail-glued 3/8-inch plywood sheathing (fig. 3d); and (4) adding $2\frac{1}{2}$-inch-thick insulation in the 2-inch space between the plywood sheathing of the wall illustrated in figure 3e. The nail-glued plywood sheathing was investigated because designers occasionally use this construction to obtain girder-like action from the module wall and thereby eliminate the need for continuous support.

DISCUSSION OF RESULTS

Party Wall Tests

The wall as assembled (fig. 3a) and tested in the field had an FSTC of 47. When fabricated and tested as a 9- by 14-foot wall in the laboratory, the STC was 49. This minor difference between field and laboratory performance is in keeping with field testing experience and indicates that no serious flanking of the wall occurred in the field.[4] Flanking is sound transmission by paths other than directly through the partition.

After testing the simulated field assembly in the laboratory, we removed the fiberboard sheathing and reassembled the wall for a second test. In the second test, the STC of the wall was 51. The transmission loss curves for the wall, with and without fiberboard sheathing, are compared in figure 4. The STC of 51 agrees with previous laboratory tests of such a wall construction.[5] Thus, the removal of the sheathing improved the STC of the wall instead of reducing it.

The next modification of the original wall was to add 1/2-inch-thick sound-deadening board under the gypsum wallboard on one side-- thereby representing a more effective

[3] The laboratory, made available through courtesy of Simpson Timber Co., was designed to measure sound transmission by the Acoustical Materials Association (now Acoustical & Insulating Materials Association) test procedure AMA-1-II. Sound transmission loss of all walls was measured in accordance with the AMA-1-II procedure. In addition, the sound transmission loss of the first wall was measured in accordance with ASTM E90-70. The room volumes of the laboratory (1,760 cubic feet) were smaller than those recommended for measurements of transmission loss at a frequency 125 Hertz but were acceptable. Both procedures gave an STC of 49.

[4] T. B. Heebink and J. B. Grantham. Field/laboratory STC ratings of wood-framed partitions. Sound & Vibration 5(10): 12-16, 1971.

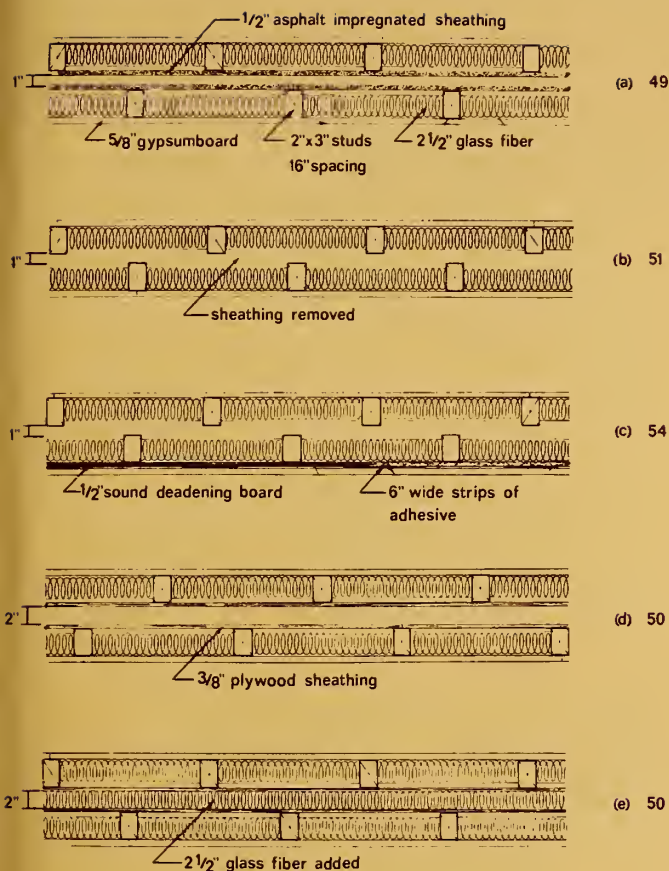[5] Western Wood Products Association. Sound control. Portland, Oregon, 1971.

(a) 49 — 1/2" asphalt impregnated sheathing; 5/8" gypsumboard; 2"x3" studs 16" spacing; 2 1/2" glass fiber

(b) 51 — sheathing removed

(c) 54 — 1/2" sound deadening board; 6" wide strips of adhesive

(d) 50 — 3/8" plywood sheathing

(e) 50 — 2 1/2" glass fiber added

Figure 3.--Construction of the wall
as formed in the field (a) and
as modified in four ways for
laboratory testing (b, c, d, e).
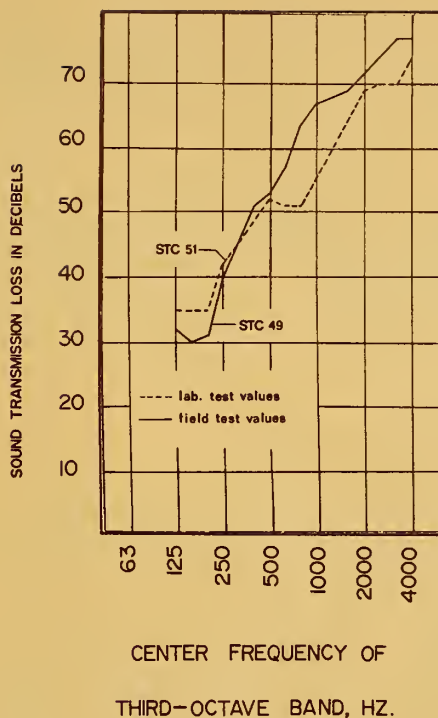

CENTER FREQUENCY OF

THIRD—OCTAVE BAND, HZ.

Figure 4.--Improvement in
airborne sound insulation
of a double wood-framed
wall--achieved by increas-
ing the transmission loss
at low frequencies.

use of material (replacing two 1/2-inch-thick layers of fiberboard sheathing). The gypsum wallboard face was then strip laminated and nailed[6] over sound-deadening board. This modification was made without disturbing the wall frame. When the wall was tested, the STC was 54 (fig. 4). Thus, the removal of the two layers of fiberboard sheathing, plus the addition of one layer of fiberboard under the gypsum board, improved the STC from 49 to 54.

A further modification of the wall incorporated 3/8-inch plywood--to simulate plywood sheathing on the outside of the module. The nailed and glued plywood covered the full wall height. (In actual practice, the plywood would extend from the bottom of the floor joists to the top of the ceiling joists to give maximum strength and stiffness to the wall.) This wall construction was the same as for the field-tested wall (fig. 3a), except nail-glued plywood replaced the 1/2-inch-thick fiberboard sheathing and the space between the two parts of the wall (between sheathing) was

[6] The 7d nails were spaced 12 inches apart around the perimeter of the sheet and at the one-third points on the intermediate studs.

5

increased from 1 to 2 inches. The STC of this wall was 50 or about the same as that of the wall used in the motel.

A minor modification of the plywood-sheathed wall was made by separating the wall and adding 2½-inch-thick glass fiber in the 2-inch space. The STC of the wall was unchanged by this addition.
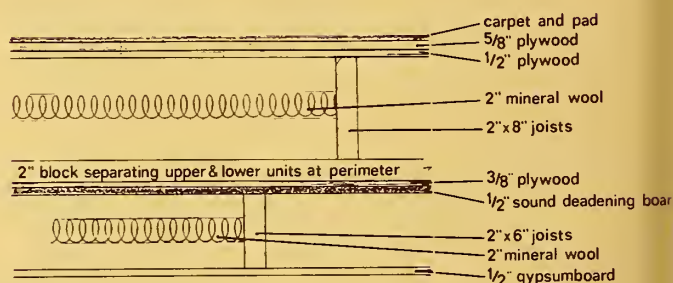
Floor-Ceiling Tests

The floor-ceiling assembly formed when one modular unit was set atop another (as illustrated in figs. 2 and 5) was tested only in the field. The FSTC of 49 indicates good resistance to airborne sound transmission. Field-measured resistance to impact sound transmission gave an IIC of 71 for the carpeted floor and 42 for the small area of vinyl tiled floor. The above values are in line with the sound insulation provided in good motels but are not as high as might be expected for a double joist system--with separate floor and ceiling joists (fig. 5). A test was conducted at the Michael J. Kodaras Laboratories (their number KAL-224-15) of a relatively simple double-joist floor-ceiling system (see fig. 5). An IIC of 80 was realized without benefits of sound-deadening board or extra plywood over the ceiling joists. Comparing results, then, shows that neither the combined plywood sound-deadening-board top cover of the first floor modules nor the thermal insulation in the ceiling joist space contributed to the sound attenuating properties in the modular construction.

A review of laboratory ratings of floor-ceiling assemblies (see footnote 5) reveals that sound-deadening board is effective in reducing sound transmission if applied between the subfloor and underlayment (as could be accomplished in the floor of the upper units). For maximum acoustical benefit, the underlayment should be glued, not nailed, to the sound-deadening board. Benefits thus obtained are similar to those obtained in the wall illustrated in figure 3c as compared with the wall illustrated in figure 3b.

Mere omission of the plywood sound-board cover from the lower modules is believed to improve the resistance to low-frequency sound transmission and raise the field test

FIELD-TESTED STC 49

carpet and pad
5/8" plywood
1/2" plywood
2" mineral wool
2"x 8" joists
2" block separating upper & lower units at perimeter
3/8" plywood
1/2" sound deadening board
2"x 6" joists
2" mineral wool
1/2" gypsumboard

LABORATORY-TESTED STC 51

carpet and pad
1⅛" plywood
2"x8" joists
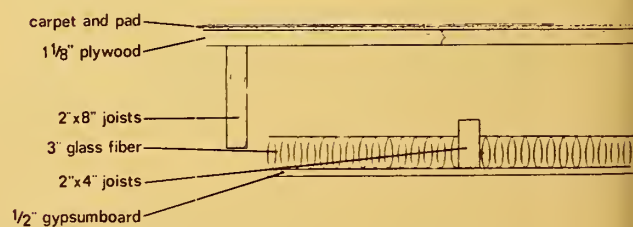3" glass fiber
2"x4" joists
1/2" gypsumboard

Figure 5.--Floor-ceiling assemblies with separate floor and ceiling joists.

6

values shown in figure 6 almost to those of the laboratory test values. A similar omission improved the wall rating from 49 to 51 (fig. 4). Omission also of the plywood sound-deadening-board cover may reduce the peak values of impact sound pressure level (fig. 7) and thereby improve the IIC ratings of the modular assemblies.

Omitting the plywood sound-deadening-board cover from first floor modules could improve the resistance to sound transmission
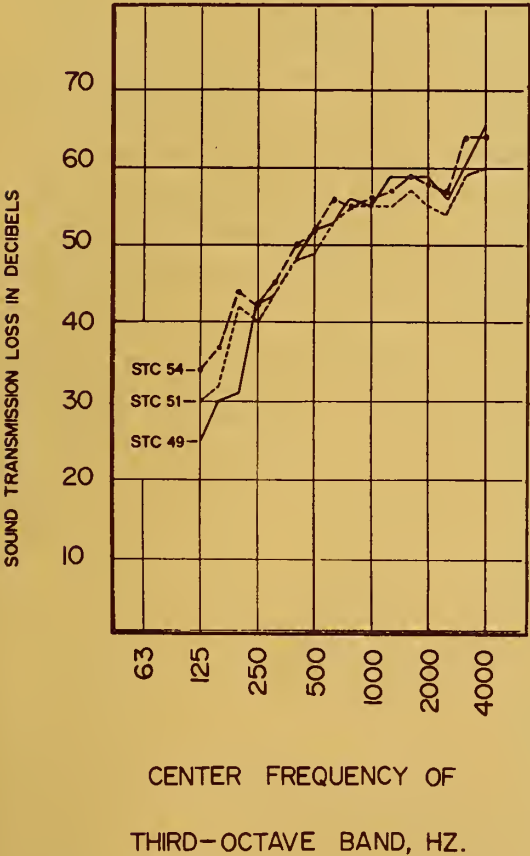
but would decrease resistance to racking during transportation and erection. We hope the report of these tests will aid designers and builders of modular wood-framed buildings, in their choice of materials and assemblies, to provide the required (or desired) strength and sound insulation at lowest cost.

CONCLUSIONS

The possibility that covering materials used to stiffen and protect three-dimensional factory-built motel

Figure 6.--Comparative resistance to airborne sound transmission of assemblies with separate floor and ceiling joists.
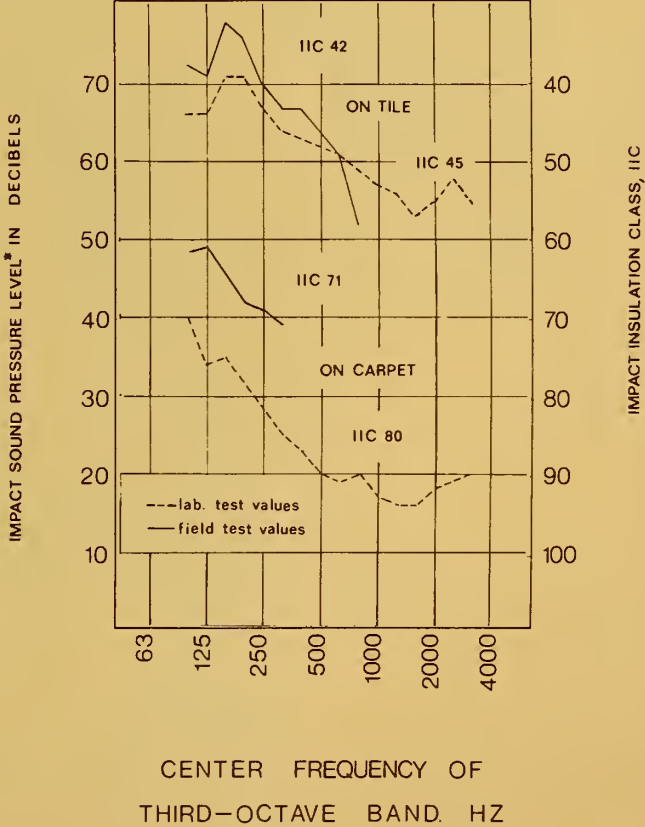
*NORMALIZED TO $A_0 = 10\,m^2$

Figure 7.--Comparative resistance to impact sound transmission of assemblies with separate floor and ceiling joists.

units during transportation and erection may be ineffective in insulating against sound transmission has been demonstrated in one instance.

Acoustical measurements in a well-designed modular motel revealed that the airborne sound insulation of the dividing walls and floor-ceiling assemblies between living units was acceptable (STC 47 and 49, respectively), and the impact sound insulation of the carpeted floors was excellent (IIC 71). However, the contribution of the protective coverings used on the modular units, including a combination of plywood sound-deadening-board cover over the ceiling joists and 1/2-inch-thick asphalt-impregnated sheathing on the outer walls, did not improve sound insulation over what experience indicates should be expected without such covering materials.

As a test of this belief, the wall construction used in the motel was reconstructed in a laboratory and its resistance to airborne sound transmission determined as STC 49 under carefully controlled conditions. When retested with the 1/2-inch-thick sheathing removed, the sound insulation was improved (STC 51). When 1/2-inch-thick sound-deadening board was applied beneath the gypsum board to only one side of the double wall, the sound insulation was improved still further (STC 54).

Thus, the amount and disposition of construction materials which may be ideal for structural rigidity may not be the most effective arrangement for acoustical performance. The designer's task is complicated, therefore, by a need to achieve the best compromise between weather protection, strength, sound insulation, and cost.

*   *   *   *   *